AN ERGONOMIC EVALUATION OF A FRONT SUPPORT CHAIR FOR FORWARD LEANING SEATED TASKS

by

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The prevalence of low back pain in industry has contributed to employee days away from work and therefore decreased production. Low back pain is even more pervasive in industries where the work requires the employee to lean forward while performing the task. Leaning forward is natural for tasks that require visual acuity and manual manipulation. Chairs that are usually provided have backrests with lumbar support; however, leaning forward makes the utilization of the backrests insufficient or non-existent. This study explores and examines if a “front-rest” (as opposed to a backrest) provides better support for the employees during the performance of their tasks. Two groups of subjects were used to test a chair that had a backrest and front-rest feature. Each group had 15 men and 15 women whose anthropometric measurements were taken. All subjects completed questionnaires on their comfort in the chair. The subjects then worked on a jigsaw puzzle for an hour, and then completed the same questionnaires. The heart rate of the subjects was monitored throughout the activity. The differences between the before and after results on the questionnaires and heart rate were analyzed statistically. The results showed no difference between the front-rest group and the backrest group. There were trends in the data that indicate more research is needed, and best practices were used. This study represents a baseline that can be used for further study into the issue of low back pain in forward leaning tasks.

AN ERGONOMIC EVALUATION OF A FRONT SUPPORT CHAIR FOR FORWARD LEANING TASKS

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INTRODUCTION

Evaluating chairs and workstations has been the focus of numerous research studies to decrease the prevalence of lower back pain (LBP) and cumulative trauma disorders (CTDs). While chair features such as a backrest are important in supporting the correct back posture, most results indicate backrests are underused or are insufficient when performing a forward leaning task (Vergara & Page, 2000). Many manufacturing and industry jobs require performing forward leaning tasks. These activities can range from sewing to product inspections. Forward leaning task operations require the worker to lean forward to view and handle their work (Yu, Keyserling & Chaffin, 1988). While it is less fatiguing to sit rather than stand while performing the required work, this can contribute to a higher prevalence of lower back pain for employees due to increased spinal disc pressure (Yu, Keyserling & Chaffin, 1988).

Many researchers have evaluated how the workstation can be improved, which is not always useful across different industries due to the limited scope (Hsiao & Keyserling, 1991). Chairs with adequate lumbar support are hard to find and configure since the task requires the employee to lean forward and away from the support. This study explores and examines if a "front-rest" (as opposed to a backrest) provides better support for the employees during the performance of their tasks. A specific frontal support from a particular chair is evaluated to see if there is a measurable decrease in discomfort while performing a forward leaning task.

Statement of the Research Question

For forward leaning tasks, an evaluation is necessary to determine if front chair support is a better support for decreasing LBP. To be considered a better support, there should be less fatigue and stress on the body at the end of the task or activity. Specifically, a chair with a front support should create less discomfort than a chair with a backrest for the same task. Measuring the decreased discomfort in the performance of forward leaning tasks involves a subjective assessment, as well as biometric data. This study uses three subjective questionnaires to measure and evaluate the difference in discomfort. In addition a heart rate monitor was used to measure the heart rate of each subject. The research null hypothesis (H_0) for each of the various measurements is that there is no difference between the front-rest chair and backrest chair. For each measurement, the alternative hypothesis (H_A) is that the above null hypothesis is rejected and that a difference between the front-rest and backrest exists.

LITERATURE REVIEW

Industry practices have developed over time to allow workers to sit while performing tasks, and there are many reasons why seated work has increased as opposed to standing work. One major reason is the culture. In industrialized countries, the sitting position has become the normal body posture. Commuting to and from work, sitting at work and then sitting again at home has become a characteristic of modern times (Grandjean & Hunting, 1977). Another reason sitting has become commonplace in the industry is to reduce fatigue for the workers and increase productivity. Performance and discomfort have a strong correlation when discussing the pain of the worker and its effect on production (Corlett & Bishop, 1976). Retaining trained workers who can give more effort to their job and take less sick time is a valuable resource, especially in the manufacturing segment (Dillard & Schwager, 1997). Keeping workers healthy and working is beneficial to the bottom line of industry employers. Sitting instead of standing to perform tasks reduces the "physical strain on the body. Indeed, in a sitting position we relax the muscles in the feet, legs, and – to some extent – in the trunk" (Grandjean & Hunting, p.137, 1977). In many cases, standing is not optional since working a foot pedal or control is necessary to perform a task, as is the case with sewing. Even if sitting is not required the advantages of employers providing seats on productivity are too great to ignore. Throughout the literature there are three repetitive reasons why sitting is better for productivity than standing: "(1) sitting consumes less energy than standing and reduces fatigue; (2) sitting reduces mechanical stresses on the lower extremities; and (3) sitting reduces the hydrostatic pressure associated with lower extremity circulation" (Yu, Keyserling & Chaffin, p. 1765, 1988, and Helander, Czaja, Drury, Cary & Burri, p. 250 1987). Easing mechanical stresses and lowering the occurrence of CTD and LBP will help the performance of many industries. Performance and discomfort have a strong correlation when discussing the pain of the worker and its effect on production (Corlett & Bishop, 1976).

Sitting and Back Pain

Despite the fact that sitting during tasks helps to reduce overall fatigue; there is still a high prevalence of lower back pain in workers who perform forward leaning seated tasks due to the compression of the spine in seated positions (Yu, Keyserling & Chaffin, 1988). "Unfortunately, complaints about low-back pain are also widespread among seated workers. In fact, it has been shown that intradiscal pressures in the lumbar region of the spine can actually be greater while seated than standing" (Stevens, p. 1, 2004). This compression is greater in seated tasks and increases when leaning forward which creates lumbar pain (Claus, Hides, Moseley & Hodges, 2008). More specifically as the trunk is bent forward the natural curve of the spine is flattened, and the pressure on the discs is increased considerably. Sitting in general causes this flattening but the turning of the hips to bend the trunk forward creates greater pressure in the lumbar region of the spine. The flexing of the lumbar area and increased pressure, especially on the 3rd, 4th and 5th lumbar discs is considered a strain and an unnecessary load on the discs (Grandjean & Hunting, 1997 and Yu, Keyserling & Chaffin, 1988).

The major causes of compression may be due to lack of backrest use or inadequate backrest support during the performance of tasks that require high visual acuity such as sewing, inspection, and video display terminal use (Li, Haslegrave & Corlett, 1995). In these cases, the need to lean forward comes from the desire of the employees to gain a better view of their work. During this seated activity, the weight of the arms trunk and head are carried by the lower back and surrounding tissues. The increased pressure can change the curvature of the lumbar spine. The lack of back support promotes lordosis in the lower lumbar area, and this increases stress on the spinal structures (Makhsous, Lin, Hanawalt, Kruger & LaMantia, 2012).

The prolonged maintenance of a static position, even a sitting one, can increase fatigue, especially in certain muscle groups (i.e., shoulders, lower and upper back, and legs). When sitting in a single position for an extended period of time, the muscles that maintain that position will work persistently to support the position. This can cause muscle fatigue as those muscles have no opportunities to relax from maintaining the position (Graf, Guggenbühl & Krueger, 1995). Another reason that LBP increases is due to the need of the discs in the spine to take nourishment through the pumping of fluid through the spine with body movement (Graf, Guggenbühl & Krueger, 1995). These combined reasons have created an issue that has potentially contributed to the increase of cumulative trauma disorders centering on lower back pain. A backrest is normally what is used to support the spine while seated. However, if the backrest is underused or is improperly supporting the posture then musculoskeletal stresses are introduced (Yu & Keyserling, 1989).

Forward Leaning Tasks

Forward leaning tasks are a problem for industries. The sewing industry is a prime example of work that is usually performed in a seated position. Therefore, the benefits of ergonomic chairs and workstations for sewing have been researched with numerous studies. While using a chair for industrial sewing operations can reduce body fatigue, it also can introduce musculoskeletal stresses (Dillard & Schwager, 1997). "Certain industrial operations (e.g. smallparts assembly and inspection, sewing, etc.) require workers to maintain prolonged seated postures. The resulting biomechanical stresses may result in increased rates of back pain and disability" (Yu, Keyserling & Chaffin, p. 1767, 1988). Watchmaking is another industry that requires the worker to maintain a forward leaning position in a constant manner (Grandjean & Hunting, 1977). Bench assembly, microscopy, inspection, Video Display Terminal (VDT) work in addition to sewing all require a large amount of visual activity. The visual demands of the task affect the posture of the neck and trunk, and it involves manual manipulations (Hsiao & Keyserling, 1991). The visual and manual demands that industry work requires creates a situation where the worker feels the need to lean forward while performing their tasks.

The industries where forward leaning tasks are the normal posture makes the backrests of the chairs used less effective. The position of the hands affect reach, elevation, and upper arm abduction which is important for manual tasks, but vision also has an important influence (Li, Haslegrave & Corlett, 1995). These postures and movements affect workers to the point of causing a detrimental effect on these industries: musculoskeletal disorders such as LBP and complaints of pain are a major cause of work disability and sick leave (Delleman & Dul, 2002). Adjusting the workstation and chair is not always as helpful as predicted since the complaints of LBP may be aggravated by more than just the forward inclined posture, such as the angles of the ankles and knees (Delleman & Dul, 2002).

Chair Evaluations

Changing the height and the features of the work table and chairs are normally the first action of safety professionals, but that does not fix the problems with forward leaning. If the workstation height is raised, then the neck and head become more upright, and the trunk straightens (Delleman & Dul, 2002). This does not address the position of the upper limbs. Nathan-Roberts, Chen, Gscheidle & Rempel, (2008) studied a number of tasks as well as the adjoining postures: "this study investigated the effects of forward leaning active, reclined relaxed, and upright active tasks on lower and upper body postures. A variety of common chairs were used while subjects performed the tasks" (p. 692). The independent variable was the task, and they found that "the task that we are performing while seated can have a significant effect on posture. Understanding the effects of task on posture enables us to better design chairs to improve comfort and productivity" (Nathan-Roberts, p. 692, 2008). After evaluating four different tasks and postures, the task with visual and manual demands led to an observed forward leaning posture: "the writing task was associated with increased head, thoracic cage, and pelvis flexion compared to the other tasks….For the writing task, it was common to see a participant hunched forward, directly above their paper….these postures are likely due to the lower visual target activities" (Nathan-Roberts, p. 695, 2008). The work supported the theory that the fatigue/discomfort involved with forward leaning tasks affects industry: "This study showed that task type can have a significant impact on posture, which in turn can affect performance and the occurrence of musculoskeletal disorders" (Nathan- Roberts, p. 695, 2008). The task determines postural stress and the chairs for forward leaning tasks have been found to be insufficient in past research.

Being able to change the posture by adjusting the chair is possible in some cases but not in many of the forward leaning cases. In those instances, it is difficult to find a more suitable chair than the traditional work chair with a backrest (Grandjean & Hunting, 1977). The Drury &

Coury (1982) study "makes the point that seating is only a means to an end rather than an end in itself. The motivation for sitting is the task performed in the seat rather than the seat itself so the best that can be hoped for in seating is to achieve a 'state of non-awareness' of the seat. Despite this, performance changes in the task as a function of seating are notoriously difficult to detect," (p. 195). If the chair is only the means to an end in the performance of a task, then the chair evaluation must include the specific task (Drury & Coury, 1982).

Measuring Discomfort

Chair studies have been done numerous times in the past, and one of the biggest issues is measuring comfort and discomfort. "Discussion of measuring methods is subject to one serious limitation: *to date there is no way of directly measuring the extent of the fatigue itself.* There is no absolute measure of fatigue, comparable to that of energy consumption which can be expressed in such simple terms as kilojoules. All the experimental work carried out so far *has merely measured certain manifestations or 'indicators' of fatigue*" (Kroemer & Grandjean,   p. 204, 1997). Measuring symptoms or lack of comfort seems to be the standard process, and this process is highly subjective. Comfort itself has so many facets that defining the features to be measured is difficult: "It seemed reasonable to consider 'industrial comfort' as a concept; however, with a threshold level below which the operator would not be distracted from his work. The measure of it would be levels of *discomfort*, judged on a scale" or defined otherwise (Corlett & Bishop, p. 177, 1976). For the purposes of this study, the main component of discomfort to be measured is bodily pain that stems from the posture and effort involved from a specific task (Corlett & Bishop, 1976). These bodily pains and discomfort are the subjective measures that are common throughout the literature and chair/workstation evaluation studies.

The subjective nature of measuring discomfort and comfort levels causes problems when trying to collect data. Helander, Czaja, Drury, Cary & Burri (1987) outline clearly these issues with data collection. They state that there are four main difficulties in evaluating comfort using subjective evaluations. The first is that many individuals are not aware of their feelings. Comfort is not as easily perceived as discomfort through sense to varying degrees. The second issue is that describing or verbalizing comfort is difficult for many individuals. The third issue is that deciding which design feature of the chair is the cause of the comfort or discomfort felt by the individual. Finally, comparing the comfort of multiple chairs adds difficulty for the individuals involved. This is due to the trouble in memorizing the sensation of comfort or discomfort long enough to perform a comparison (Helander, Czaja, Drury, Cary & Burri, 1987). These difficulties indicate that a large amount of variability should be expected when it comes to the data created from comfort assessments (Helander, Czaja, Drury, Cary & Burri, 1987). In spite of these difficulties, the subjective assessment of chairs by users is the only reliable way to monitor changes in discomfort and comfort levels (Vergara & Page, 2002).

Further axioms of chair evaluations have been defined by researchers that reduce variability on subjective assessment of chairs. "There are three basic methods of evaluating chairs….These methods use measures which compare the chair design; use fitting trials to adjust the chair to the operator and finally to have users evaluate the chairs experimentally, either in a laboratory setting or at the real workplace" (Drury & Coury, p. 195, 1982 and Helander, Czaja, Drury, Cary & Burri, p. 250, 1987). These three methods have been used to evaluate other tasks and chairs to investigate which designs will assist in lowering pain for a specific industry task. This design can be simplified to a four-part chair evaluation. Evaluate the general comfort of the chairs, and then evaluate local body part discomfort while in the chair. Outline the features of each chair using a checklist and then have the users rank the chairs (Helander, Czaja, Drury, Cary & Burri, 1987). This is consistent throughout the research on chair evaluations. Simple scales are recommended for use in these methods. While evaluating the features of the chair, the checklists create specificity and define further that it is chair comfort and not user comfort that is being measured (Branton, 1969). In order to channel this information, the scales describing the features, body part discomfort and overall comfort should be used (Helander, Czaja, Drury, Cary & Burri, 1987). A specific checklist is not used in this study, since only one feature is being evaluated; however the scales of comfort about the feature will be needed. In order "to evaluate the evaluation procedure, it is necessary to consider its sensitivity, validity and reliability" (Drury & Coury, p. 200, 1982). Multiple evaluations and scales are used in this study to provide more sensitive, valid and reliable data.

Representative Task

The specific task that is used to evaluate this chair feature is the completion of a jigsaw puzzle. A jigsaw puzzle requires the user to evaluate pieces visually and then manually place the pieces on the table in the space that completes the larger picture. The visual and manual nature of the jigsaw puzzle has made it an ideal source of data collection for researchers. Jigsaw puzzles are used in research for many reasons. There are elements in common with work tasks to create more opportunities for generalizations (Johnson & Hyde, 2003). A jigsaw puzzle can be a consistent task that does not introduce new variables, but allows for the changing of other variables. Because it is a well-known task, the lack of new knowledge made available through the task itself is minimal (Johnson & Hyde, 2003). Instead of limiting the subject pool to skilled workers, the amount of data collected can be increased by opening the study to unskilled subjects. The skill level required to complete a jigsaw puzzle is low, and it can be assumed that most individuals have a similar amount of prior knowledge on how they work (Johnson & Hyde, 2003). Jigsaw puzzles also facilitate the observation process for the researchers. There is a clear beginning and end to the task, which do not require interpretation since there is only on solution to the task and it is provided on the lid of the box (Johnson &Hyde, 2003). The puzzles also require work in a limited space and with visual and manual manipulation. This represents the target industrial audience that performs forward leaning tasks that require visuospatial activity in a limited space. The jigsaw puzzle provides the restrictions of the target task in relation to the posture required to maintain access to the puzzle pieces and box lid. The construction also requires the maintenance of resource space by the individuals that participate in the study as well (Johnson & Hyde, 2003). This is representative of the workspace in many industries. The use of jigsaw puzzles in research has been found to be a highly successful way to mitigate task management variables. Richardson & Vecchi (2002) determined that their study results confirmed the use of a jigsaw puzzle to be a sensitive, powerful and reliable tool. Puzzles are used heavily in psychological research and task oriented observations. Most of those studies focus more on the completion of the puzzle and have found success; however, this study uses the puzzle in order to provide a consistent task that does not require special knowledge to complete.

METHODOLOGY

The University & Medical Center Institutional Review Board (IRB) Office of East Carolina University has reviewed and approved the application for this evaluation (see Appendix A for UMCIRB 14-001360). This included the questionnaires, consent/screening forms, data collection sheet and study protocol. The study was executed according to the protocol submitted and approved.

Subjects

The subjects consisted of 30 males and 30 females who are all working professionals accustomed to working eight-hour days. They were divided into two groups. Group A (15 males/15 females) performed the activity using the front-rest (see Figure 1) and Group B (15 males/15 females) performed the activity without the front-rest, using the chair as a normal backrest chair (see Figure 2). Anthropometric data was taken on each participant (see Appendix B) and used to create similar groups (calculated to cover the same representative percentiles of the U.S. Population). The two groups were not randomized but balanced by gender and anthropometry. Informed consent and a general health survey were discussed with each participant to verify that all subjects were of good health and did not have previous injuries or trauma that could affect the data (see Appendix C). The participation in this study was voluntarily, and the subjects did not receive any monetary compensation.

Figure 1: Setup with Front-rest

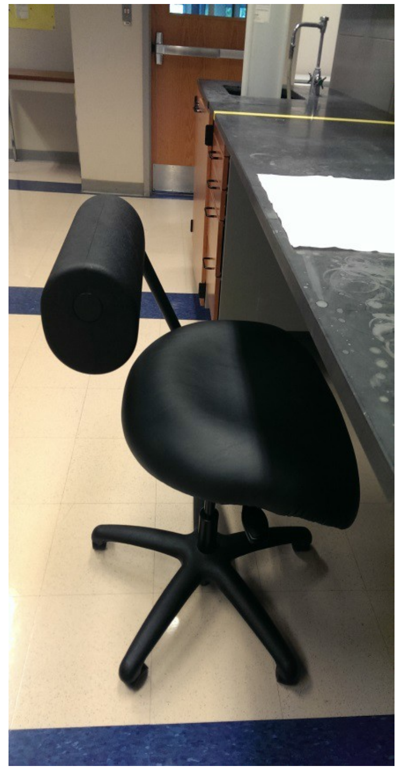


Figure 2: Setup with Backrest

Instrumentation

- Neutral Posture AbStool™/AbChair™: Figure 3
- Workstation: Table 36 inches in height and 550 piece jigsaw puzzle
- Heart rate measured with the Mio Alpha wristwatch: Figure 4
- Video/Picture Camera to record subjects and analyze posture as supplemental information
- Anthropometer
- SAS JMP Software 10.0.2
- Protractor
- Weight Scale
- Timer

Figure 3: Neutral Posture AbStool™/AbChair™

Figure 4: Mio Alpha wristwatch

Data Collection

In addition to the anthropometric data, each participant was given a heart rate monitoring watch (Figure 4) to wear for the duration of the activity and then had the anthropometric measurements taken. Each subject was then introduced to the chair and adjusted to participant comfort. Measurements were taken of the chair setup once the chair was adjusted (Figure 5). Heart rate was measured every fifteen minutes during the activity as well. All data was recorded manually using the data collection sheet (Appendix A).

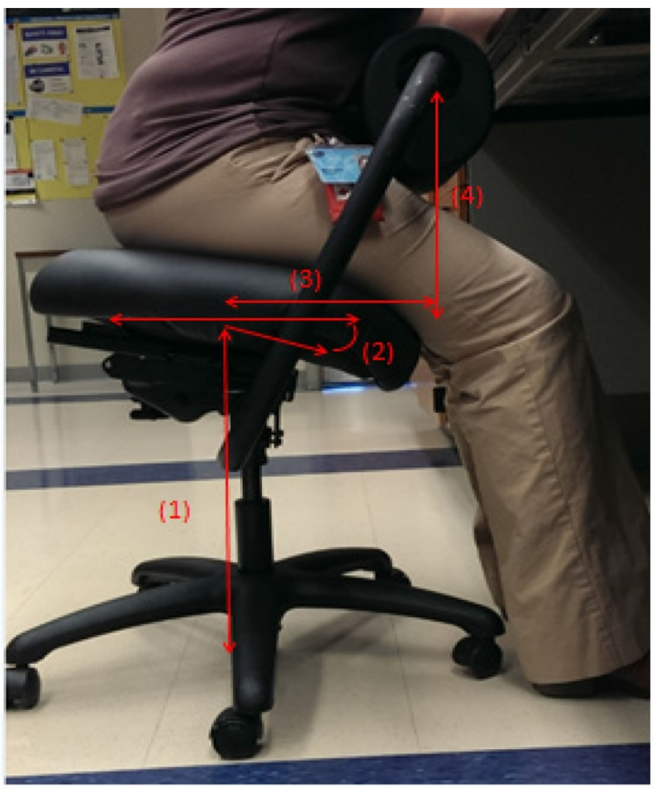


Figure 5: Seat Measurements

Seat Height: distance between floor and center of the seat pan (1)
Seat Angle: Angle of the seat pan from the horizontal (2)
Front/backrest Distance: Distance of the center of the front/backrest to the center of the seat pan (horizontal measurement) (3)
Front/backrest Height: Vertical distance of the center of the front/backrest to the center of the seat pan (4)

Questionnaires

Three questionnaires were given to the subjects to complete before the beginning of the activity. A 550 piece jigsaw puzzle was placed on a table with a work surface 36 inches high, and the subjects worked on the task for one hour. The same three questionnaires were completed again immediately following the activity. The assessments used in this study were chosen for multiple reasons. In past studies, the variability of the data is influenced by the subjective nature of the evaluations, "it would be preferred if there were physical measures that could predict comfort" (Helander, Czaja, Drury, Cary & Burri, p. 261, 1987). To reduce the effect of variability, multiple questionnaires of different types/scales were chosen. The Borg-RPE-Scale® (1982) measures perceived exertions and discomfort and is a well-known ergonomic scale (see Appendix D). Anderson, Anderson & Deuser (1996) performed a study where a Perceived Comfort Scale (Appendix E) was investigated and created to evaluate a participant's perception of a setup. It contains 11 different words the subject must rate, and the combination of the negative and positive words can be used to give the researcher more understanding of the results. Using negative and positive results in the scale is also part of the Bipolar Comfort Discomfort Scale (Appendix F). This scale is the product of a study performed on different types of numerical scales to see which provide the most effective data on perceived discomfort. Of the scales used, the Bipolar Comfort Discomfort Scale was the most sensitive scale in the study. Combining these scales with the measurement of heart rate will provide an in depth view of the subject's discomfort. Each measurement evaluation is compared against the other for further verification.

Statistical Analysis

For the purpose of this thesis study, an independent samples t test (which is referred to as a one-way ANOVA in SAS JMP) was performed on the differences of pre and post activity responses. These differences were compared by groups and gender on outcomes. The before activity response was subtracted from the after activity response to provide the differences for statistical analysis. The responses were collected and in addition to the heart rate provided five measurements of difference for analysis. Due to the multiple tests, in order to control for Type I error, all statistic tests were computed at the 0.01 level of significance. A Brown Forsythe test is used to compare the variances of the groups and examine the equality of variance between the groups for the ANOVA analysis.

The Borg-RPE-Scale® (1982) measures perceived exertions and discomfort, local (lower lumbar) and overall before and after activity. Two measurements provide information for the discomfort of the study participant.

1. *H_0 = There is no difference in localized discomfort between the use of the front-rest and the backrest.*
2. *H_0 = There is no difference in overall discomfort between the use of the front-rest and the backrest.*

The Perceived Comfort Scale (Craig A. Anderson © 1995) measures the perceived comfort of the activity setup (chair settings and table) before and after the activity. There are eleven word components to this scale that are averaged for a final measure.

3. *H_0 = There is no difference in perceived discomfort between the use of the front-rest and the backrest.*

A Bi-polar Comfort-Discomfort Scale (Hernandez, Alhemood, Genaidy & Karwowski, 2002) is used to measure the perceived level of comfort of the chair before and after the activity.

4. *H_0 = There is no difference in discomfort (using the bipolar scale) between the use of the front-rest and the backrest.*

The heart rate is used to measure the baseline comfort level of the subjects before, during and after the activity.

5. *H_0 = There is no difference in heart rate of subjects between the use of the front-rest and the backrest.*

The alternative hypothesis (H_A) is that the above null hypotheses are rejected and that a difference between the front-rest and backrest exists.

H_A= There is a difference in discomfort/heart rate between the use of the front-rest and backrest.

RESULTS

The experimental group (A) and control group (B) were matched as closely based on anthropometric measurements. The groups are described in Table 1 by age, weight and anthropometric information. Each group contains 15 men and 15 women. Group A was the experimental group (chair used with front-rest), and Group B was the control group (chair used with a backrest). The anthropometric measures were calculated to reflect the percentiles of the U.S. Population (Fryar, Gu, & Odgen, 2012 and Kroemer & Grandjean, 1997).

Table 1: Minimum and Maximum Summary of Anthropometric Data

	Men		**Women**	
Group	**A**	**B**	**A**	**B**
Age in Years	27-61	34-63	24-63	23-57
Weight in Pounds	165-248	160-299	121-231	107-266
Stature*	21-82	26-84	7-80	21-87
Shoulder Height*	39-93	34-92	28-89	33-90
Elbow Height*	30-97	36-97	46-92	34-97
Hip	57-98	61-98	40-95	61-98
Sitting Height*	2-25	2-28	3-70	2-59
Sitting Eye Height*	3-34	3-69	3-69	3-93
Sitting Shoulder Height*	3-61	3-72	10-85	2-95
Sitting Elbow Height*	2-61	2-84	11-89	3-93
Buttock-Knee Length*	8-66	3-75	5-67	5-79
Popliteal-Knee Length*	3-98	7-74	2-80	10-81
Knee Height*	15-90	23-87	2-82	39-95
Popliteal Height*	38-93	48-90	20-93	57-99
Shoulder Elbow Length*	51-97	25-98	18-98	25-93
Elbow Fingertip Length*	13-48	18-77	8-75	5-85
Forward Grip Reach*	28-98	26-80	33-97	23-89

***in percentile of U.S. adult population (Kroemer & Grandjean, 1997)**

The before and after differences documented in each measure for the groups are displayed in Table 2 using five-number summaries and the means. The five-number summary represents each quartile of the data starting with the minimum number, the median as the half (or 2nd quartile) and ending with the maximum number. In addition, measurements of the chair were taken for each subject after they were set up for the task. The summary of those measurements is displayed in Table 3 by group and gender.

Table 2: Means and Five Number Summaries of Differences

Difference Measure	Group	Mean	Minimum	1st Quartile	Median	3rd Quartile	Maximum
Heart Rate	A	0.1	-15	-4	-2	5	14
	B	-0.47	-25	-6.25	0	3.25	23
Borg Scale Overall Discomfort	A	1.6	-2	0	0	3	9
	B	2	0	0	1	3.25	7
Borg Scale Local Discomfort	A	1.07	-6	-1	0	3	9
	B	2.23	-2	0	1.5	3.5	8
Bipolar Scale Discomfort	A	-1.22	-10	-3.5	-1	1	5.5
	B	-1.38	-11	-2.875	-1	0	5
Perceived Discomfort - Comfortable	A	-0.17	-2	-1	0	0.25	1
	B	-0.53	-2	-1	0	0	1
Perceived Discomfort - Cozy	A	-0.2	-2	-1	0	0	2
	B	-0.17	-2	0	0	0	1
Perceived Discomfort - Miserable	A	0.2	-1	0	0	0	2
	B	0.27	-1	0	0	0.25	2
Perceived Discomfort - Painful	A	0.4	-1	0	0	1	2
	B	0.53	-2	0	0	1.25	2
Perceived Discomfort - Pleasant	A	-0.13	-2	-1	0	0	2
	B	-0.63	-2	-1	0	0	1
Perceived Discomfort - Restful	A	-0.1	-2	-1	0	1	1
	B	-0.23	-2	-1	0	0	1
Perceived Discomfort - Snug	A	-0.33	-3	-0.25	0	0	1
	B	-0.3	-2	-1	0	0	0

Perceived Discomfort - Soothing	A	0.1	-2	-0.25	0	1	2
	B	-0.13	-1	0	0	0	1
Perceived Discomfort - Stressful	A	0.07	-2	0	0	0	2
	B	0.3	-1	0	0	1	1
Perceived Discomfort - Uncomfortable	A	0.2	-3	0	0	1	3
	B	0.6	-2	0	1	1	2
Perceived Discomfort - Unpleasant	A	0.33	-2	0	0	1	2
	B	0.5	-1	0	0	1	2

Table 3 – Minimum and Maximum Summary of Seat Adjustment Measurements

	Men		**Women**	
Group	**A**	**B**	**A**	**B**
Seat Height (cm)	50-55.7	48.6-56.5	51.8-55.4	48.7-55.6
Seat Angle (degrees)	2-16	0-4	1-16	0-3
Horizontal Distance to front/backrest (cm)	13.5-22.4	25.2-33.3	15.1-24.6	25.6-32.9
Vertical Distance to front/backrest (cm)	21.4-31.7	23.2-27.8	22.2-35.8	22-30.5

The Brown Forsythe test was used to examine the equality of variances assumption for each outcome variable. The p-values are shown in Table 4. The results determined that a further analysis of the A and B groups could be performed on the data assuming they have equal variances. A one-way ANOVA was performed for each measure (Borg, Bipolar, Perceived Comfort and heart rate) on groups A and B. The results indicated that there was no significant statistical difference present in the measured data. None of the measures returned evaluation p-value at the 0.01 level of significance; therefore, the null hypotheses cannot be rejected.

Table 4 – P Values of Statistical Hypothesis for Each Measure

Group	Condition	Discomfort Measure	One Way ANOVA p-value	Brown Forsythe p-value
		Borg Scale Overall	0.56	0.48
A	Front-rest	Borg Scale Local	0.19	0.71
versus	Versus	Bipolar C/D Scale	0.84	0.83
B	Backrest	Perceived Comfort Scale*	0.46	0.37
		Heart rate	0.79	0.32

***Average of all words**

Additional analysis was conducted to examine the data. The raw data of the before and after responses for each discomfort measure were analyzed individually using the SAS JMP ANOVA. Many of the before and after responses were found to be not statistically different from each other. The only measures that showed a statistical difference at the 0.01 level in the before and after measures were: Borg Scale Overall and Borg Scale Local, Perceived Comfort Painful and Perceived Comfort Unpleasant. These results suggest that overall the responses of the subjects did not change from the beginning of the activity to the end.

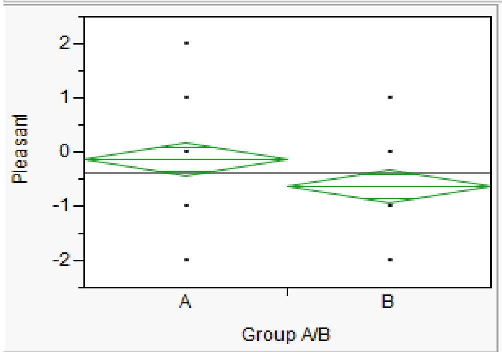
The only item that came close to the 0.01 level of significance for discomfort measures was the "Pleasure" rating from the Perceived comfort scale. The "Pleasure" rating for the two groups was measurably different with a p-value of 0.02 (see Figure 6). However, the lack of difference in before and after responses indicates that those in Group A thought the chair was pleasant before and after the test and did not indicate any change in fatigue as a group. To the subjects the front-rest seemed more pleasant than the backrest from the start of the activity.

An analysis comparing gender on the outcome variables was performed. The one-way ANOVA was calculated on each discomfort measure by gender and indicated that gender had no effect on the result measures. A bivariate (linear) fit of the discomfort measures was performed against the anthropometric measurements. The analysis of the anthropometric data on the responses also displayed no statistical correlations. The seat measurement data taken on the test chair did show a correlation with response values. A bivariate fit of the seat height had an effect on responses. The correlations and p-values are shown in Table 5. The higher the seat height was set for the subject; the higher the negative responses reported. However, this is true across both groups (A/B) and therefore does not support the rejecting the any of null hypotheses. It should be noted though that the control group (backrest) had higher seat adjustments in general and lower angles than the test group (front-rest). The table was not adjusted throughout the study and was set at 36 inches for all subjects in both groups.

Table 5: Bivariate Fit of Discomfort Measure by Seat Height

Discomfort Measure	**Correlation of Linear Fit**	**ANOVA p-value on Fit**
Borg Scale Local	0.26	0.0295
Bipolar Comfort Discomfort	0.30	0.0196
Perceived Comfort - Comfortable	0.33	0.0105
Perceived Comfort - Stressful	0.35	0.0069

Oneway Analysis of Pleasant By Group A/B



Oneway Anova

Summary of Fit

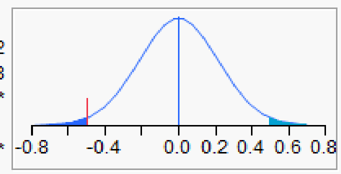
Rsquare	0.084874
Adj Rsquare	0.069096
Root Mean Square Error	0.834941
Mean of Response	-0.38333
Observations (or Sum Wgts)	60

t Test

B-A

Assuming equal variances

Difference	-0.50000	t Ratio	-2.31932
Std Err Dif	0.21558	DF	58
Upper CL Dif	-0.06847	Prob > |t|	0.0239*
Lower CL Dif	-0.93153	Prob > t	0.9880
Confidence	0.95	Prob < t	0.0120*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group A/B	1	3.750000	3.75000	5.3792	0.0239*
Error	58	40.433333	0.69713		
C. Total	59	44.183333			

Figure 6: One-Way ANOVA on “Pleasant”

CONCLUSIONS

The data does not support the Neutral Posture AbStool™/AbChair™ in reducing discomfort or fatigue for a forward leaning task. The only difference in response data is that the experimental group found the front-rest to be more "Pleasant" than the control group found their chair with the backrest. The response data from the measures were not significantly different before the activity and after the activity. This suggests that the duration of the activity and the activity itself were not sufficient to create before and after data sets that were measurably different. The purpose of the analysis was to measure the discomfort of the activity and verify the difference. It may be speculated that one hour was not sufficient to create enough discomfort to measure for the majority of the responses. Since some of the before and after response groups were different, and the different scales produced the same overall results, the use of the questionnaires proved to be an adequate form of measurement. There were no observable trends in the heart rate data that could be tied to the results of the questionnaires. The task was not strenuous enough to cause a significant difference in before and after results. For short term, non-exhaustive work the heart rate data demonstrates its ineffectiveness as a measure of fatigue or discomfort.

The subjects that adjusted the seat to have a higher distance from the seat to the floor had higher negative responses. This could be due to a lack of support for the participant's feet as they worked. The control group had higher seat heights than the experimental group and the experimental group did not comment as much about or request footrests since the angle of the seat allowed them to put their feet on the legs of the chair. The anthropometric data did not reflect this trend since stature did not affect responses. The subjects who could touch the floor but had a higher seat adjustment still had higher negative responses. The negative responses were consistent across both groups with regard to seat height and therefore do not reflect a conclusion on the front-rest chair as a fatigue lowering feature.

RECOMMENDATIONS

Although the conclusions do not support this chair as a solution for decreasing LBP, further investigation on this chair is still needed. The most effective replication of this study would be to extend the activity for a longer period of time. Most of the previous work on chair evaluation is performed using an eight-hour activity period with a half hour lunch break. This would help to further differentiate the level of discomfort between the two groups. In addition, this chair comes with more options from the vendor. The chair used in the study had minimal features to reduce variables; however, there is perhaps a better option for the 36 inch work table that could be implemented and tested. Many of the features of the other models include footrest bars, padded backrests and are more adjustable than the model used in this study.

The chair and length of the test are not the only variables that could be adjusted or reevaluated in the future. Other factors observed during the course of the study could contribute to discomfort variables. Measurement of neck pain is something that could be included or measured locally in addition to LBP. Discomfort in the neck was commented on by some of the subjects as they filled out their questionnaires. Flexion of the neck while performing forward leaning work was present in much of the literature, a new study should include research into neck pain and the flexion angles that affect these activities.

Another option to be considered is the measurement of production or completion of work. In this study, the number of completed puzzle pieces could have been used to measure production. The measurement of increased or decreased production can be evaluated and compared for fatigue correlation (Guastello, Malon, Timm, Wienberger, Gorin, Fabisch & Poston, 2014). In fact, increased production on a task that is non-strenuous may be a better measurement of discomfort.

The results of this study were informative and the baseline for further evaluation into this activity has been achieved. The questionnaires provided thorough information that can direct the actions and measurements in further research. The ability to search for further trends based on anthropometry with multiple subjects lends more validity to the data. Using three separate questionnaires and scales that can verify results within the study is a reasonable practice for future chair evaluations given the subjective nature of that evaluation. Choosing representative tasks may be helpful in future chair studies to widen the data pool and applicability of the results. Overall, the data and methodology of this study contributes to the body of work being performed on chair evaluations to decrease the pain associated with forward leaning tasks in industry.

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APPENDIX A: IRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · **www.ecu.edu/irb**

Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
To: Michelle Cooke
CC: Hamid Fonooni
Date: 8/20/2014
Re: UMCIRB 14-001360
An Ergonomic Evaluation of a Front Support Chair for Forward Leaning Seated Tasks

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 8/19/2014 to 8/18/2015. The research study is eligible for review under expedited category #4, 6, 7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Name	Description
Bipolar Comfort Scale	Surveys and Questionnaires
Borg Scale Questionnaire	Surveys and Questionnaires
Informed Consent	Consent Forms
Participant Data Collection	Data Collection Sheet
Participant Screening	Consent Forms

Perceived Comfort Scale	Surveys and Questionnaires
Thesis Proposal	Study Protocol or Grant Application

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

APPENDIX B: DATA COLLECTION SHEET

Participant Information:

Participant Number	**Group A or B**	**Male/Female**	**Age**	**Weight**
#	**A/B**	**M/F**	**years**	**Lbs.**

Biometric Data

Heart Rate in BPM

30 minutes before Activity	Start of Activity	15 minutes into Activity	30 minutes into Activity	45 minutes into Activity	End of Activity

Anthropometric Measurements

Measured in mm

Stature (Height)	
Shoulder Height	
Elbow Height	
Hip Height	
Sitting Height	
Sitting Eye Height	
Sitting Shoulder Height	
Sitting Elbow Height	
Buttock-Knee Length	
Buttock-Popliteal Length	
Knee Height	
Popliteal Height	
Shoulder-Elbow Length	
Elbow-Fingertip Length	
Forward Grip Reach	

Chair with Subject Measurements

Seat Height	**Seat Angle**	**Front/backrest Distance**	**Front/backrest Height**	**Participant Height**
inches	degrees	inches	inches	inches

APPENDIX C: PARTICIPANT SCREENING

Instructions: If you are interested in participating in this study which will take approximately 2-3 hours to complete and you meet all of the requirements, please sign the bottom and return form to Michelle Cooke. Once the form is reviewed, you will be contacted to schedule a participation time and given a participant number.

Requirements to Participate:

You must be a healthy adult (≥18 years of age)

Are you 18 years of age or older? □ Yes □ No

Please review the following statements. If **any** of the following statements apply to you, you **must exclude yourself from participation in this study**.

Are you currently pregnant or breastfeeding?	□ Yes □ No
Have you had Back Surgery?	□ Yes □ No
Are you currently being treated for any Cumulative Trauma Disorder?	□ Yes □ No

Participant Name:
Participant Signature:
Date:

APPENDIX D: BORG SCALE QUESTIONNAIRE

Instructions to the Borg-RPE-Scale®

During the work we want you to rate your perception of discomfort/exertion, i.e. how strenuous the exercise feels to you and how tired you are. The perception of exertion is mainly felt as strain and fatigue in your muscles.

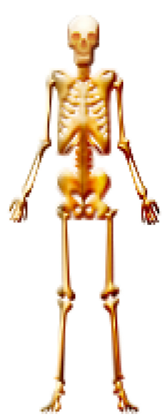
Use this scale from 6 to 20, where **6** means “No exertion at all” and **20** means “Maximal exertion.”

9 Very light. As for a healthy person taking a short walk at his or her own pace.
13 Somewhat hard. It still feels OK to continue.
15 It is hard and tiring, but continuing is not terribly difficult.
17 Very hard. It is very strenuous. You can still go on, but you really have to push yourself, and you are very tired.
19 An extremely strenuous level. For most people, this is the most strenuous exercise they have ever experienced.

Try to appraise your feeling of exertion and fatigue as spontaneously and as honestly as possible, without thinking about what the actual physical load is. Try not to underestimate, nor to overestimate. It is your own feeling of effort and exertion that is important, not how it compares to other people’s. Look at the scale and the expressions and then give a number. You can equally well use even as odd numbers.

Please provide a number for overall body fatigue and localized back pain.

6	No exertion at all
7	
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion



Result Numbers: ____________ ____________

APPENDIX E: BIPOLAR COMFORT DISCOMFORT SCALE QUESTIONNAIRE

Bi-polar Comfort Discomfort Scale

This scale consists of a number line that can be used to describe the comfort/discomfort of the chair. Try to appraise your feeling of comfort or discomfort of the chair itself as spontaneously and as honestly as possible. Look at the scale and the expressions and then give a number.

-10	maximum discomfort
-9	
-8	
-7	
-6	
-5	strong discomfort
-4	
-3	moderate discomfort
-2	weak discomfort
-1	
-0.5	just noticeable discomfort
0	
0.5	noticeable comfort
1	
2	weak comfort
3	moderate comfort
4	
5	strong comfort
6	
7	
8	
9	
10	

Result: ________________________

APPENDIX F: PERCEIVED COMFORT SCALE QUESTIONNAIRE

Perceived Comfort Scale

This scale consists of a number of words that can be used to describe the conditions of a room or set up. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel each word describes this setup of the chair and table right now, that is, at the present moment. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

________ comfortable	___________ cozy	___________ miserable	________ painful
________ pleasant	___________ restful	___________ snug	________ soothing
________ stressful	___________ uncomfortable	___________ unpleasant	